# Influence of Shock Wave on the Flutter Behavior of Fan Blades Investigated

Modern fan designs have blades with forward sweep; a lean, thin cross section; and a wide chord to improve performance and reduce noise. These geometric features coupled with the presence of a shock wave can lead to flutter instability. Flutter is a self-excited dynamic instability arising because of fluid-structure interaction, which causes the energy from the surrounding fluid to be extracted by the vibrating structure. An in-flight occurrence of flutter could be catastrophic and is a significant design issue for rotor blades in gas turbines. Understanding the flutter behavior and the influence of flow features on flutter will lead to a better and safer design. An aeroelastic analysis code, TURBO, has been developed and validated for flutter calculations at the NASA Glenn Research Center. The code has been used to understand the occurrence of flutter in a forward-swept fan design. The forward-swept fan, which consists of 22 inserted blades, encountered flutter during wind tunnel tests at part speed conditions.
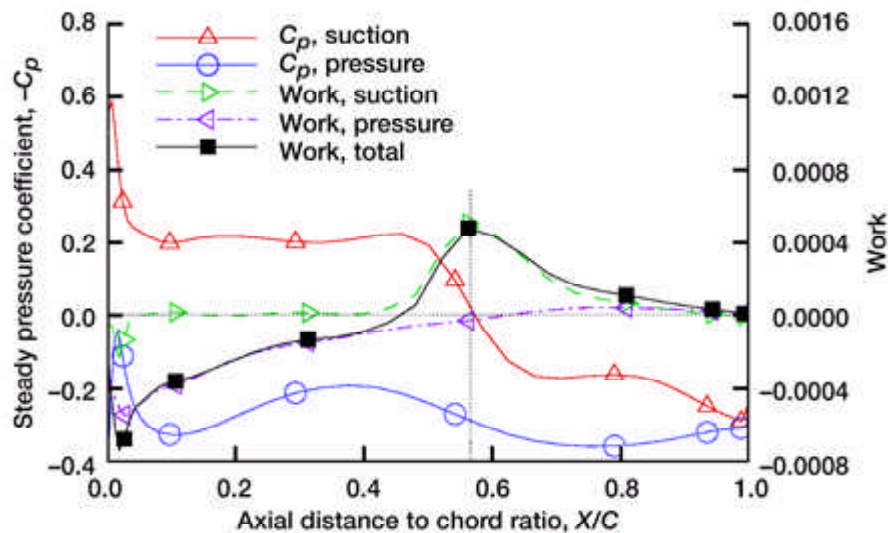

Pressure coefficient and work distribution at 95-percent span for the forward-swept fan blade operating near stall.

The TURBO code solves the Reynolds-averaged three-dimensional Navier-Stokes equations to calculate the work done on a vibrating blade by the surrounding fluid. The work is calculated for a prescribed harmonic motion in the mode and nodal diameter pattern of interest. The work done over one cycle of blade vibration can be converted to a more meaningful damping value referred to as aerodynamic damping. The flutter point can then be calculated by extrapolating the performance characteristics at which the aerodynamic damping goes to zero. The TURBO code calculated the observed flutter of the forward swept fan, correctly identifying the mode and nodal diameter of the observed flutter. The study indicated that the shock wave location and strength have a strong influence on blade stability. The preceding figure shows the distribution of work on the

blade surface at 95 percent of the span. Also shown on this figure is the steady pressure coefficient identifying the shock wave and its location. It is clearly seen that the work done by the fluid is centered around the shock wave. It was found that as the operating conditions changed and the shock wave location moved on the blade surface, the area of work associated with the shock wave also moved. The work calculated was found to be strongly dependent on the shock wave strength as well.

The following figure shows the distribution of total work on the blade surface for different mass flow conditions. Both stabilizing and destabilizing areas of work were found to be associated with shock waves present on the blade surfaces. For the fan geometry analyzed, we found the suction surface shock wave to be destabilizing, whereas the pressure surface shock wave had a stabilizing effect. We also found that accurate blade shape, accounting for deformations due to operating aerodynamic and centrifugal loading, is important for the accurate prediction of the flutter boundary.
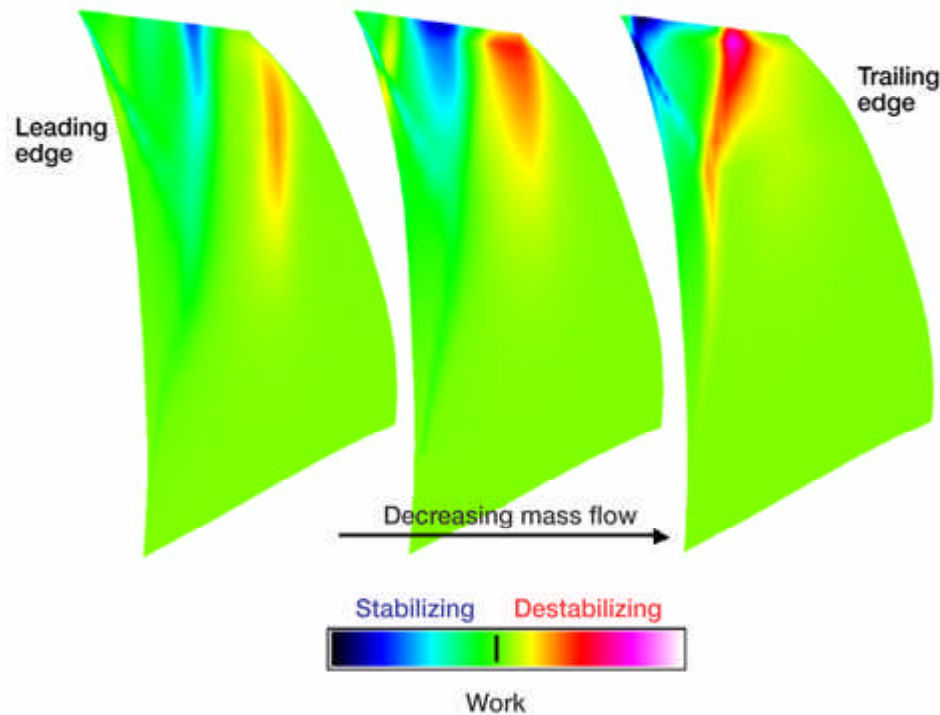
Work distribution on the blade surface for various mass flows operating at a part speed operating condition.

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